Work Plan for Pilot Testing of Circulation Well with UV-Peroxide Advancd Oxidation System at Former Northrop Grumman Y-12 Facility Fullerton, California

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February 1, 2011

Ms. Ann Sturdivant
Santa Ana Regional Water Quality Control Board
3737 Main Street, Suite 500
Riverside, California 92501

SUBJECT: WORK PLAN FOR PILOT TESTING OF CIRCULATION WELL WITH UV-PEROXIDE ADVANCED OXIDATION SYSTEM AT FORMER NORTHROP GRUMMAN Y-12 FACILITY IN FULLERTON, CALIFORNIA

Dear Ms. Sturdivant:

GeoKinetics has completed bench testing of an advanced oxidation system on behalf of Northrop Grumman Systems Corporation in response to Regional Water Quality Control Board Clean-up and Abatement Order #R8-2003-108 dated November 14th, 2003. This system uses Ultra-Violet (UV) light along with low concentrations of hydrogen peroxide to destroy Volatile Organic Compounds within groundwater. The UV light source is used in-lieu of ozone in order to eliminate the bromate generation that occurred in conjunction with the initial phase of the pilot test. The bench testing results for the modified system indicate it can effectively reduce the concentrations of the target VOCs to drinking water MCLs, or lower. The results are presented in the attached submittal along with a Work Plan for a short term test of the modified advanced oxidation system using the existing pilot test well.

I hope this information is helpful to you and the proposed testing meets with your approval. Please do not hesitate to contact me if you have any questions or comments.

Sincerely,
GEOKINETICS, INC.

Glenn D. Tofani, GE/RCE/REA
Principal Engineer

attachment

1.0 Background: A pilot test of a groundwater recirculation well (CW-1) was performed at the former Northrop Grumman Systems Corporation (Northrop Grumman) Y-12 site between October 2009 and November 2010. The well extracted groundwater from the upper portion of the Shallow Aquifer and utilized an in-casing advanced oxidation system to destroy dissolved Volatile Organic Compounds (VOCs) before directing the treated groundwater into the lower portion of the Shallow Aquifer. The locations of the pilot test well, and nearby monitoring wells, are shown in Figure 1, and a schematic illustrating the construction of the pilot test well is provided as Figure 2. The advanced oxidation treatment process involved the addition of low levels of hydrogen peroxide (3.7 to 8.8 mg/L) and ozone (5.5 to 6.2 mg/L) to the groundwater in a static mixer located at the outlet of the in-casing circulation pump. This process is illustrated in Figure 3. Ozone and hydrogen peroxide react immediately upon contact to form hydroxyl radicals ($OH^{\cdot}$) and molecular oxygen (O_2), as illustrated in Figure 4. The hydroxyl radicals possess sufficient oxidation potential to sever the chemical bonds that form organic molecules such as tetrachloroethylene (PCE) and trichloroethylene (TCE). The pilot test results indicate this treatment system was effective in reducing VOC levels to below drinking water standards.

A potential by-product of the ozone-peroxide treatment process is bromate, which is formed from the oxidation of naturally-occurring bromide within the groundwater. Bromide is naturally present in the groundwater within the project area at concentrations ranging from 50 to 200 mg/L. Bromate is a carcinogen with a maximum drinking water contaminate level (MCL) of 10 μg/L. Bromate generation has been documented in water supply systems where ozone has been added to treat and disinfect potable water. The available research indicates bromate is created through direct oxidation by ozone. Hydrogen peroxide and/or hydroxyl radicals typically have not been shown to generate bromate at detectible levels. The addition of hydrogen peroxide has been shown to reduce the potential for bromate formation when ozone is used for water treatment purposes. The in-casing reactor for the pilot test well was specifically designed by APT Water Inc. to minimize the potential for bromate generation.

During the pilot test, groundwater samples were collected from the test well and nearby monitoring wells on several occasions to screen for the presence of bromate. These samples were analyzed by a state-certified laboratory in accordance with testing protocol EPA 300.1b - the most widely utilized procedure for detecting bromate in groundwater. Until October of 2010, each of the samples that was submitted for analysis was reported to have non-detectible levels of bromate. However, the Orange County Water District collected groundwater samples from monitoring wells in the pilot test area on October 4, 2010 and subsequently reported the detection of bromate at concentrations up to 152 μg/L. The subsequent analysis of additional samples using the EPA 300.1 protocol, as well as a more sophisticated Liquid Chromatography - Mass Spectrometry (LC-MS) procedure, confirmed the presence of bromate in the effluent of the pilot test well at concentrations between 230 and 430 μg/L. A summary of the bromate analytical results that have been compiled to date is provided in Table 1, and the associated laboratory analytical reports are included as Attachment A. As shown, the last set of groundwater samples was collected for analysis on November 1, 2010. Pumping of the pilot test well was terminated immediately after the collection of those samples. Additional groundwater samples will be collected and analyzed under a separate Work Plan to monitor and confirm the attenuation of the bromate levels.

The data collected during the pilot test indicates groundwater remediation utilizing a recirculation well with an in-casing advanced oxidation treatment system is technically and economically feasible, provided the generation of bromate can be eliminated. Even operating at the relatively low circulation rate of 60 gallons per minute (gpm), the pilot test well was able to generate a relatively large zone of clean water within the lower portion of the Shallow Aquifer and reduce groundwater VOC levels in monitoring wells located several hundred feet downgradient of the test well. The groundwater flow pattern induced during the operation of the pilot test well is illustrated in Figures 5 and 6 based upon groundwater modeling, as well as the monitoring results obtained throughout the recent pilot test. The recent bromate levels measured in the upper and lower sections of the pilot test well indicate approximately 40% of the effluent water from the well was recirculated to the upper casing.

Although APT Water Inc. has indicated it is possible to modify the existing in-casing reactor to reduce bromate levels below the 10 μg/L MCL, Northrop Grumman elected to evaluate an alternative advanced-oxidation approach that is unlikely to generate any detectible quantity of bromate. This alternative involves the use of an ultraviolet (UV) light source along with hydrogen peroxide. When exposed to the proper wavelength of UV light, a hydrogen peroxide molecule will degrade into two hydroxyl molecules. This simple reaction is illustrated in Figure 7. The second phase of the reaction where organic compounds (PCE, TCE, etc.) are oxidized by the hydroxyl radicals is identical to that discussed previously for the ozone-peroxide process. However, the UV-Peroxide alternative has not been shown to generate detectible levels of bromate in the available documentation.

The existing pilot test well hardware was designed such that it could be converted to a UV-Peroxide system, if necessary. The proposed modifications to the existing ozone-peroxide system involve replacing the APT in-casing reactor with an array of UV lights sealed within fused silica housings. GeoKinetics has recently completed bench tests using this type of system in a 10-inch diameter stainless steel well casing at our Irvine facility. GeoKinetics performed these tests using groundwater from the former Y-12 site at pressures consistent with those found in the lower portion of the pilot test well. The objectives of this bench testing were to:

1. Determine the destruction efficiency of the UV-Peroxide process;

2. Determine the number of UV lamps that will be required to accommodate the target flow rate of the pilot test well (i.e. 50 to 60 gpm); and

3. Confirm the absence of bromate in the effluent from the system.

This submittal is intended to provide the Regional Water Quality Control Board (RWQCB) with the results of the recent UV-Peroxide bench tests along with a Work Plan to perform short term testing of this advanced oxidation process at the former Y-12 site using the existing pilot test well. This testing is being performed in response to Clean-up and Abatement Order R8-2003-108 issued by the RWQCB on November 14^{th}, 2003.

2.0 Bench Testing Results: Bench testing of the UV-Peroxide advanced oxidation system involved a single array of six Atlantic Ultraviolet lamps sealed within individual fused-silica housings. Each lamp has a rated UV output of approximately 20 watts at a wavelength of 254 nanometers. The lamps were spaced evenly at a 3.5-inch radius around a one-inch diameter stainless steel drop pipe. PVC brackets were attached to the drop pipe at the top and bottom of the 48-inch long fused silica housings to secure the lamps. The electronic ballasts for the lamps were sealed in a 3-inch diameter stainless steel housing that was positioned above the lamp assembly. The wiring to the ballast housing, and from the ballast housing to each lamp, was sealed in water-tight polyethylene tubing. The lamp assembly was placed in an 8-foot long section of 10-inch diameter stainless steel casing. This is the same size and type of casing that was used to construct the pilot test well (CW-1). The upper end of the test casing was fitted with a flange and 3/4-inch thick top plate such that it could be pressurized to simulate the operating conditions that exist in the lower section of the pilot test well. A schematic of the bench test system is provided as Figure 8, while photographs of the system are provided as Figures 9 and 10.

A total of six bench tests were performed. For each test, the stainless steel casing was filled with groundwater collected at the former Y-12 site. The UV lamp system was installed and an external pump was then activated (Figure 8) to circulate water from the top to the bottom of the casing at the rate of 60 gpm. A water sample was then collected from a sampling port on the casing to determine the levels of VOCs in the water at the start of the test. A small quantity of hydrogen peroxide was then added to the water in the well casing to achieve a target concentration. The UV light system was then activated and additional water samples were collected from the casing at predetermined intervals. The water samples were submitted to a state-certified laboratory (Orange Coast Analytical) for analysis of VOC levels in accordance with EPA 8260 protocol. This testing procedure was repeated using three different doses of hydrogen peroxide on two separate occasions. The test results are summarized in Table 2 and Figures 11 and 12. The laboratory analytical reports associated with these tests are included as Attachment B.

The initial bench tests were performed on November 29, 2010 using peroxide doses of 3, 6, and 12 mg/L. The water used for this bench test was collected from CW-1 on November 15th, 2010. As indicated in Table 2, the initial VOC levels in the groundwater during the first series of bench tests were relatively low - 8.2 μg/L for PCE and 4.7 μg/L for TCE. The PCE and TCE levels measured in the upper casing of CW-1 during the last quarterly sampling event (in October 2010) were 34 μg/L and 18 μg/L, respectively. The lower VOC levels measured in the samples collected on November 15th, 2010 suggest the contaminant levels in the upper portion of the pilot test well have decreased since pumping of the well was suspended on November 1st, 2010. This condition is consistent with the higher groundwater VOC levels measured just to the north of the CW-1 location. During its operation, CW-1 was expected to capture VOC-impacted groundwater from that area. With the well idle, the VOC levels in the upper casing are likely to be lower.

On December 15th, 2010, a second series of bench tests were performed to evaluate the performance of the UV-Peroxide system on water having higher VOC levels. This series of tests used groundwater collected from monitoring well NMW-3 (Figure 1), as opposed to CW-1, which likely still contained low levels of bromate from the past operation of that well. Monitoring well NMW-3 is located at a sufficient distance upgradient of CW-1 such that detectible levels of bromate were not likely to be present in the groundwater at that location. During this series of tests, PCE and TCE were added to the test water to achieve concentrations more typical of those that were recorded for samples collected from the upper casing of CW-1 during the prior operation of the well. As indicated in Table 2, initial PCE and TCE levels as high as 47 μg/L and 11 μg/L were used during this series of tests.

The bench test results indicate the UV-Peroxide system is effective in destroying the target VOCs within a relatively short time period. As illustrated in Figures 11 and 12, the amount of UV exposure time required to achieve drinking water MCLs depends upon the initial VOC level and the rate of peroxide addition. As can be seen in these figures, the rate of VOC degradation was nearly constant with respect to time at the lower peroxide dosages (i.e. 5 mg/L and lower). At higher peroxide dosages (i.e. 10 mg/L and above), the degradation rate was initially much more rapid, then progressively slowed as the VOC levels decreased. At the relatively low VOC levels that presently exist in the upper casing of CW-1, the test results indicate MCLs can be reached at a peroxide dosage of 6 mg/L with less than 20 seconds of exposure. With the higher VOC levels that have been measured in the past, approximately 60 to 90 seconds of UV exposure at peroxide dosages of 10 to 20 mg/L is likely to be required to achieve MCLs.

An additional water sample was collected from the test casing following the completion of the 12 mg/L peroxide test on November 29th, 2010. That sample was submitted to Exova Laboratories for bromate analysis in accordance with LC-MS procedures. The results of that analysis indicated a bromate concentration of 20 μg/L. As previously discussed, the water utilized for this bench test was collected from the upper CW-1 casing on November 15th, 2010. The previous groundwater sample collected from that casing on November 1st, 2010 contained 95 μg/L bromate. The 20 μg/L concentration of bromate measured in conjunction with the bench tests appears to represent residual bromate from the prior operation of the ozone-peroxide system. These results also indicate the bromate levels within CW-1 are attenuating quickly.

Another water sample was collected and submitted to Exova Labs for bromate analysis at the completion of the second series of bench tests on December 15th, 2010. This sample was collected from the test casing following the completion of the test with the 20 mg/L peroxide dosage. As indicated previously, this series of bench tests was performed using groundwater collected from NMW-3 in order to eliminate the elevated residual bromate concentrations that were present in the CW-1 water. The results of this analysis indicate a bromate concentration of 0.23 μg/L in the effluent water from the UV-Peroxide treatment system. This is consistent with typical background levels that have been reported in other samples collected from the area and indicates no significant bromate generation from the bench test. These results are consistent with available documentation regarding the operation of this type of advanced oxidation system.

The UV lamp assemblies will be subject to hydrostatic pressures on the order of 50 psi in the lower section of the CW-1 well casing. The lamps and ballasts that are sealed within these assemblies must remain dry in order to function. In order to test the integrity of the housings for the lamps and ballasts, those components were submerged and pressurized to 85 psi within the test casing for a period of three weeks. The current draw of the system (0.5 amps per lamp) was monitored to confirm that each lamp remained operational during this period. The lamp assembly was also removed and inspected every week to check for any sign of leakage. The lamp and ballast assemblies remained leak-free and functional under these test conditions.

3.0 Proposed Pilot Test: As outlined above, bench testing of the UV-Peroxide advanced oxidation system indicates it is capable of destroying the target VOCs to drinking water MCLs with only a few tens of seconds of UV exposure. Short term field testing of this system is proposed in the pilot test well (CW-1) at the former Y-12 site to further evaluate its potential for effectively remediating the VOC-impacted groundwater at this site. It is anticipated that the proposed testing can be completed in a single day. The testing will involve the installation and operation of an 18-lamp system. The test well will be operated at pumping rates of approximately 20, 40, and 60 gpm in conjunction with this testing. At each pumping rate, the peroxide dosage will be progressively increased from 5 mg/L, to 10 mg/L, and finally to 20 mg/L before starting over at the 5 mg/L dosage at the next highest pumping rate. With the three different pumping rates and three different peroxide dosages, there will be a total of nine individual tests. It is anticipated that each individual test will last approximately 30 minutes.

Water samples will be collected from both the upper and lower screened intervals of the test well, and from adjacent monitoring well MW-17, during the tests. These samples will be analyzed for VOCs, total chromium, chrome VI, and bromate in accordance with standard testing procedures. The proposed sampling and testing matrix is illustrated in Table 3.

The proposed configuration of the UV-Peroxide pilot test system is shown in Figure 13. As indicated, the system will consist of three independent UV assemblies with six lamps each, for a total of 18 lamps. The distance between the top and bottom of the UV exposure zone is approximately 15 feet. This configuration will provide approximately 180 seconds of UV exposure time at a pumping rate of 20 gpm, 90 seconds at 40 gpm, and 60 seconds at 60 gpm. As shown in Figure 13, a mixing vane and centralizer will be installed above and below each UV lamp assembly. These components will induce a rotational flow pattern as the water moves down the casing in order to insure relatively uniform and complete UV exposure. The vanes also centralize the lamp assemblies and insure they do not contact the casing. Hydrogen peroxide will be added to the groundwater within the Upper Chamber (Figure 13) through a stainless steel capillary tube. The peroxidated water will pass through the Lower Chamber and the Static Mixer before entering the lower well casing where it will be exposed to the UV light. Effluent water samples will be collected from the lower casing using two fixed sampling pumps installed below the third set of UV lamps. The operation of the UV lamps will be monitored throughout the test. As indicated previously, each lamp draws 0.5 amps of current at 120 volts (pre-ballast). Accordingly, the total system current with all 18 lamps in operation will be 9 amps. If any of the lamps fail to function properly during the test, the test will be terminated, or the pumping rate will be adjusted, as necessary, to compensate for any non-operational lamps. The UV-Peroxide treatment equipment will be removed from the pilot test well at the completion of the tests.

We will prepare and submit a summary report for the pilot test activities upon receipt of the associated laboratory analytical reports for the groundwater samples. A tentative schedule for the proposed pilot test is provided in Figure 14.

4.0 Closing: We hope the Pilot Test Work Plan outlined in this submittal is acceptable to the RWQCB. The testing of the Circulation Well / Advanced Oxidation System completed to date indicates this approach has the potential to economically remediate VOC-impacted groundwater in-situ without generating waste or potentially harmful by-products. We would like to move forward with the proposed short-term test of this system as expeditiously as possible upon your review and approval of this Work Plan. Please do not hesitate to contact any of the undersigned if you have any questions or comments.

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attachments

TABLE 1

GROUNDWATER ANALYTICAL DATA
PILOT TEST OPERATING PARAMETERS AND BROMATE RESULTS
Y-12 PILOT TEST; ANAHEIM CALIFORNIA

Well ID[a] & (Screen Interval)	Date Sampled	Date Reported[f]	Ozone Loading[b] (mg/l)	Peroxide Loading[b] (mg/l)	Circulation Pump Rate (gpm)	Result[c] (µg/l)			Lab
						EPA 300.1-B	EPA 300.1-B (With Extra Filtering)	LC-MS/ IC-MS	
MCL	--	--	--	--	--	10			--
CW-1 (upper casing / reactor influent) (110' - 148')	2/1/10	2/9/10	6.2	3.7	80	ND<5	-	-	Associated
	2/22/10	3/3/10	6.2	3.7	60	ND<5	-	-	Associated
	3/1/10	3/11/10	6.2	3.7	60	ND<5	-	-	Associated
	3/8/10	3/17/10	6.2	3.7	60	ND<5	-	-	Associated
	3/15/10	3/23/10	6.2	3.7	60	ND<5	-	-	Associated
	4/21/10	4/26/10	6.2	3.7	60	ND<5	-	-	Associated
	5/10/10	5/21/10	6.2	3.7	60	ND<5	-	-	Associated
	7/26/10	8/2/10	6.2	3.7	60	ND<5	-	-	Associated
	8/30/10	9/4/10	6.2	3.7	60	ND<5	-	-	Associated
	10/4/10	10/7/10	6.2	3.7	60	ND<5	-	-	Associated
	10/4/10	10/27/10	6.2	3.7	60	-	9.57	-	Associated
	10/18/10	10/29/10	6.2	3.7	60	-	-	180	Exova[e]
	11/1/10	11/12/10	5.5	8.8	60	ND<10	-	-	Test America
	11/1/10	11/16/10	5.5	8.8	60	-	-	96	Exova[e]
	11/1/10	11/29/10	5.5	8.8	60	95	-	-	OCWD
			5.5	8.8	60	-	-	94	MWH Labs[e]
			5.5	8.8	60	-	-	110	ES Babcock[e]
CW-1 (lower casing / reactor effluent) (175' - 193')	2/1/10	2/9/10	6.2	3.7	80	ND<5	-	-	Associated
	2/22/10	3/3/10	6.2	3.7	60	ND<5	-	-	Associated
	3/1/10	3/11/10	6.2	3.7	60	ND<5	-	-	Associated
	3/8/10	3/17/10	6.2	3.7	60	ND<5	-	-	Associated
	3/15/10	3/23/10	6.2	3.7	60	ND<5	-	-	Associated
	4/21/10	4/26/10	6.2	3.7	60	ND<5	-	-	Associated
	5/10/10	5/21/10	6.2	3.7	60	ND<5	-	-	Associated
	7/26/10	8/2/10	6.2	3.7	60	ND<5	-	-	Associated
	8/30/10	9/4/10	6.2	3.7	60	ND<5	-	-	Associated
	10/4/10	10/7/10	6.2	3.7	60	ND<5	-	-	Associated
	10/4/10	10/27/10	6.2	3.7	60	-	149	-	Associated
	10/18/10	10/29/10	6.2	3.7	60	-	-	430	Exova[e]
	11/1/10	11/12/10	5.5	8.8	60	ND<5	-	-	Test America
	11/1/10	11/16/10	5.5	8.8	60	-	-	230	Exova[e]
	11/1/10	11/29/10	5.5	8.8	60	237	-	-	OCWD
			5.5	8.8	60	-	-	240	MWH Labs[e]
			5.5	8.8	60	-	-	280	ES Babcock[e]
MW-15A (110' - 125')	7/26/10	8/2/10	NA	NA	NA	ND<5	-	-	Associated
	10/4/10	10/7/10	NA	NA	NA	ND<5	-	-	Associated
	10/4/10	10/11/10	NA	NA	NA	ND<5	-	-	OCWD
	10/4/10	10/27/10	NA	NA	NA	-	6.77	-	Associated
MW-15B (140' - 150')	7/26/10	8/2/10	NA	NA	NA	ND<5	-	-	Associated
	10/4/10	10/7/10	NA	NA	NA	ND<5	-	-	Associated
	10/4/10	10/11/10	NA	NA	NA	ND<5	-	-	OCWD
	10/4/10	10/27/10	NA	NA	NA	-	7.68	-	Associated
MW-15C (185' - 190')	7/26/10	8/2/10	NA	NA	NA	ND<5	-	-	Associated
	10/4/10	10/7/10	NA	NA	NA	ND<5	-	-	Associated
	10/4/10	10/11/10	NA	NA	NA	ND<5	-	-	OCWD
	10/4/10	10/27/10	NA	NA	NA	-	8.27	-	Associated
MW-16A (110' - 125')	7/26/10	8/2/10	NA	NA	NA	ND<5	-	-	Associated
	10/4/10	10/7/10	NA	NA	NA	ND<5	-	-	Associated
	10/4/10	10/11/10	NA	NA	NA	ND<5	-	-	OCWD
	10/4/10	10/27/10	NA	NA	NA	-	9.57	-	Associated
MW-16B (140' - 150')	7/26/10	8/2/10	NA	NA	NA	ND<5	-	-	Associated
	10/4/10	10/7/10	NA	NA	NA	ND<5	-	-	Associated
	10/4/10	10/11/10	NA	NA	NA	ND<5	-	-	OCWD
	10/4/10	10/27/10	NA	NA	NA	-	ND<5	-	Associated

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Well ID[a] & (Screen Interval)	Date Sampled	Date Reported [f]	Ozone Loading[b] (mg/l)	Peroxide Loading[b] (mg/l)	Circulation Pump Rate (gpm)	Result[c] (µg/l)			Lab
						EPA 300.1-B	EPA 300.1-B (With Extra Filtering)	LC-MS/ IC-MS	
MCL	--	--	--	--	--	10			--
MW-16C (185' - 190')	7/26/10	8/2/10	NA	NA	NA	ND<5	-	-	Associated
	10/4/10	10/7/10	NA	NA	NA	ND<5	-	-	Associated
	10/4/10	10/27/10	NA	NA	NA	-	ND<5	-	Associated
	10/4/10	10/11/10	NA	NA	NA	17.6	-	-	OCWD
	10/4/10	10/29/10	NA	NA	NA	-	-	20	Exova[e]
	11/1/10	11/12/10	NA	NA	NA	ND<5	-	-	Test America
	11/1/10	11/16/10	NA	NA	NA	-	-	9	Exova[e]
	11/1/10	11/29/10	NA	NA	NA	7.4	-	-	OCWD
			NA	NA	NA	-	-	4.6	MWH Labs[e]
			NA	NA	NA	-	-	11	ES Babcock[e]
MW-17A (110' - 125')	7/26/10	8/2/10	NA	NA	NA	ND<5	-	-	Associated
	10/4/10	10/7/10	NA	NA	NA	ND<5	-	-	Associated
	10/4/10	10/11/10	NA	NA	NA	ND<5	-	-	OCWD
	10/4/10	10/27/10	NA	NA	NA	-	9.11	-	Associated
MW-17B (140' - 150')	7/26/10	8/2/10	NA	NA	NA	ND<5	-	-	Associated
	10/4/10	10/7/10	NA	NA	NA	ND<5	-	-	Associated
	10/4/10	10/11/10	NA	NA	NA	ND<5	-	-	OCWD
	10/4/10	10/27/10	NA	NA	NA	-	6.99	-	Associated
MW-17C (185' - 190')	7/26/10	8/2/10	NA	NA	NA	ND<5	-	-	Associated
	10/4/10	10/7/10	NA	NA	NA	ND<5	-	-	Associated
	10/4/10	10/27/10	NA	NA	NA	-	ND<5	-	Associated
	10/4/10	10/11/10	NA	NA	NA	13.6	-	-	OCWD
	10/4/10	10/29/10	NA	NA	NA	-	-	20	Exova[e]
	11/1/10	11/12/10	NA	NA	NA	ND<10	-	-	Test America
	11/1/10	11/16/10	NA	NA	NA	-	-	50	Exova[e]
	11/1/10	11/29/10	NA	NA	NA	177	-	-	OCWD
			NA	NA	NA	-	-	190	MWH Labs[e]
			NA	NA	NA	-	-	200	ES Babcock[e]
CMT-01B1 (150' - 160')	7/26/10	8/2/10	NA	NA	NA	ND<5	-	-	Associated
NMW-1 (110' - 125')	7/26/10	8/2/10	NA	NA	NA	ND<5	-	-	Associated
NMW-2 (110' - 125')	7/26/10	8/2/10	NA	NA	NA	ND<5	-	-	Associated
NMW-3 (112' - 127')	7/26/10	8/2/10	NA	NA	NA	ND<5	-	-	Associated
NMW-4 (110' - 125')	7/26/10	8/2/10	NA	NA	NA	ND<5	-	-	Associated
	11/1/10	11/12/10	NA	NA	NA	ND<25	-	-	Test America
	11/1/10	11/16/10	NA	NA	NA	-	-	ND<1	Exova[e]
	11/1/10	11/29/10	NA	NA	NA	ND<5	-	-	OCWD
			NA	NA	NA	-	-	0.22	MWH Labs[e]
			NA	NA	NA	-	-	0.9	ES Babcock[e]
NMW-7 (109' - 124')	7/26/10	8/2/10	NA	NA	NA	ND<5	-	-	Associated
	9/24/10	10/1/10	NA	NA	NA	ND<5	-	-	Associated
	9/24/10	10/27/10	NA	NA	NA	-	37.6	-	Associated
	9/24/10	10/11/10	NA	NA	NA	76.6	-	-	OCWD
	9/24/10	10/29/10	NA	NA	NA	-	-	100	Exova[e]
	11/1/10	11/12/10	NA	NA	NA	ND<10	-	-	Test America
	11/1/10	11/16/10	NA	NA	NA	-	-	80	Exova[e]
	11/1/10	11/29/10	NA	NA	NA	63.1	-	-	OCWD
			NA	NA	NA	-	-	75	MWH Labs[e]
			NA	NA	NA	-	-	68	ES Babcock[e]

TABLE 1

GROUNDWATER ANALYTICAL DATA
PILOT TEST OPERATING PARAMETERS AND BROMATE RESULTS
Y-12 PILOT TEST; ANAHEIM CALIFORNIA

Well ID[a] & (Screen Interval)	Date Sampled	Date Reported [f]	Ozone Loading[b] (mg/l)	Peroxide Loading[b] (mg/l)	Circulation Pump Rate (gpm)	Result[c] (µg/l)			Lab
						EPA 300.1-B	EPA 300.1-B (With Extra Filtering)	LC-MS/ IC-MS	
MCL	--	--	--	--	--	10			--
NMW-9B (110' - 120')	7/26/10	8/2/10	NA	NA	NA	ND<5	-	-	Associated
	9/24/10	10/1/10	NA	NA	NA	ND<5	-	-	Associated
	9/24/10	10/27/10	NA	NA	NA	-	13.0	-	Associated
	11/1/10	11/12/10	NA	NA	NA	ND<25	-	-	Test America
	11/1/10	11/16/10	NA	NA	NA	-	-	ND<1	Exova[e]
	11/1/10	11/29/10	NA	NA	NA	ND<5	-	-	OCWD
			NA	NA	NA	-	-	0.15	MWH Labs[e]
			NA	NA	NA	-	-	ND<0.5	ES Babcock[e]
NMW-9C (190' - 200')	7/26/10	8/2/10	NA	NA	NA	ND<5	-	-	Associated
	9/24/10	10/1/10	NA	NA	NA	ND<5	-	-	Associated
	9/24/10	10/27/10	NA	NA	NA	-	ND<5	-	Associated
	11/1/10	11/12/10	NA	NA	NA	ND<5	-	-	Test America
	11/1/10	11/16/10	NA	NA	NA	-	-	25	Exova[e]
	11/1/10	11/29/10	NA	NA	NA	17	-	-	OCWD
			NA	NA	NA	-	-	16	MWH Labs[e]
			NA	NA	NA	-	-	24	ES Babcock[e]
NMW-10A (70' - 80')	7/26/10	8/2/10	NA	NA	NA	ND<5	-	-	Associated
NMW-10B (115' - 125')	7/26/10	8/2/10	NA	NA	NA	ND<5	-	-	Associated
NMW-10C (184' - 194')	7/26/10	8/2/10	NA	NA	NA	ND<5	-	-	Associated
AM-41 (190' - 200')	9/28/10	10/6/10	NA	NA	NA	ND<5	-	-	Associated
	9/28/10	10/11/10	NA	NA	NA	152	-	-	OCWD
	11/1/10	11/12/10	NA	NA	NA	160	-	-	Test America
	11/1/10	11/16/10	NA	NA	NA	-	-	190	Exova[e]
	11/1/10	11/29/10	NA	NA	NA	181	-	-	OCWD
			NA	NA	NA	-	-	210	MWH Labs[e]
			NA	NA	NA	-	-	220	ES Babcock[e]
AM-41A (156' - 166')	9/28/10	10/6/10	NA	NA	NA	ND<5	-	-	Associated
	9/28/10	10/11/10	NA	NA	NA	348	-	-	OCWD
	11/1/10	11/12/10	NA	NA	NA	320	-	-	Test America
	11/1/10	11/16/10	NA	NA	NA	-	-	340	Exova[e]
	11/1/10	11/29/10	NA	NA	NA	333	-	-	OCWD
			NA	NA	NA	-	-	330	MWH Labs[e]
			NA	NA	NA	-	-	300	ES Babcock[e]

(a) "A" = Shallow casing; "B" = Intermediate casing: "C" = Deep casing.

(b) Ozone or peroxide loading rate to reactor inlet.

(c) ND - Not detected at the reporting limit indicated.

(d) NA = Not applicable.

(e) Exova & MWH Labs = LC-MS Result, ES Babcock = IC-MS Result

(f) Date reported is date that report was received by Northrop

Table 2 - Results for Bench Testing of U.V. / Peroxide Advanced Oxidation System

TEST DATE	SAMPLE DESIGNATION	PEROXIDE ADDITION RATE	U.V. EXPOSURE TIME	VOC LEVEL (µg/L)		
				1, 1-DCE	TCE	PCE
11/29/2010	S-1	None	None	1.1	4.7	8.2
	S-2	3 mg/L	21 sec	<1.0	3.8	6.4
	S-3		42 sec	<1.0	3.0	5.0
	S-4		84 sec	<1.0	1.6	2.9
	S-5	6 mg/L	21 sec	<1.0	0.8	1.6
	S-6		42 sec	<1.0	<0.5	0.9
	S-7		84 sec	<1.0	<0.5	<0.5
	S-8	12 mg/L	21 sec	<1.0	<0.5	<0.5
	S-9		42 sec	<1.0	<0.5	<0.5
	S-10		84 sec	<1.0	<0.5	<0.5
	S-11		300 sec	<1.0	<0.5	<0.5
12/15/2010	S-1	None	None	<1.0	11.0	9.1
	S-2	5 mg/L	18 sec	<1.0	8.6	7.4
	S-3		36 sec	<1.0	5.7	6.1
	S-4		72 sec	<1.0	2.4	3.4
	S-5		180 sec	<1.0	<0.5	<0.5
	S-6	None	None	<1.0	9.5	47
	S-7	10 mg/L	18 sec	<1.0	3.5	25
	S-8		36 sec	<1.0	1.5	16
	S-9		72 sec	<1.0	<0.5	6.8
	S-10		180 sec	<1.0	<0.5	<0.5
	S-11	None	None	<1.0	6.1	46
	S-12	20 mg/L	18 sec	<1.0	1.4	21
	S-13		36 sec	<1.0	<0.5	11
	S-14		72 sec	<1.0	<0.5	3.0
	S-15		180 sec	<1.0	<0.5	<0.5

Table 3 - Proposed Sampling During Pilot Test

Event	Elapsed Time	Sample Location and Analytes		
		CW-1 Upper	CW-1 Lower	MW-17
Sample collection immediately prior to start of test	-	VOCs Chromium Bromate	VOCs Chromium Bromate	VOCs Chromium Bromate
Start pumping @ 20 gpm with 5 mg/L H_20_2	0	-	-	-
Sample collection	30 minutes	VOCs	VOCs	-
Increase H_20_2 to 10 mg/L	40 minutes	-	-	-
Sample Collection	70 minutes	VOCs	VOCs	-
Increase H_20_2 to 20 mg/L	80 minutes	-	-	-
Sample Collection	110 minutes	VOCs Chromium Bromate	VOCs Chromium Bromate	-
Start pumping @ 40 gpm with 5 mg/L H_2O_2	120 minutes	-	-	-
Sample Collection	150 minutes	VOCs	VOCs	-
Increase H_20_2 to 10 mg/L	160 minutes	-	-	-
Sample Collection	190 minutes	VOCs	VOCs	
Increase H_20_2 to 20 mg/L	200 minutes	-	-	-
Sample Collection	230 minutes	-	-	-
Start pumping @ 60 gpm with 5 mg/L H_2O_2	240 minutes	VOCs Chromium Bromate	VOCs Chromium Bromate	VOCs
Sample collection	270 minutes	VOCs	VOCs	-
Increase H_20_2 to 10 mg/L	280 minutes	-	-	-
Sample Collection	310 minutes	VOCs	VOCs	-
Increase H_20_2 to 20 mg/L	320 minutes	-	-	-
Sample collection	350 minutes	VOCs Chromium Bromate	VOCs Chromium Bromate	VOCs Chromium Bromate

Table 3 - Proposed Sampling During Pilot Test

Event	Elapsed Time	Sample Location and Analytes		
		CW-1 Upper	CW-1 Lower	MW-17
Terminate test. Initiate removal of hardware from well.	360 minutes	-	-	-
Post-Test Sampling	1 day	-	-	VOCs Chromium Bromate
	7 days	-	-	VOCs Chromium Bromate

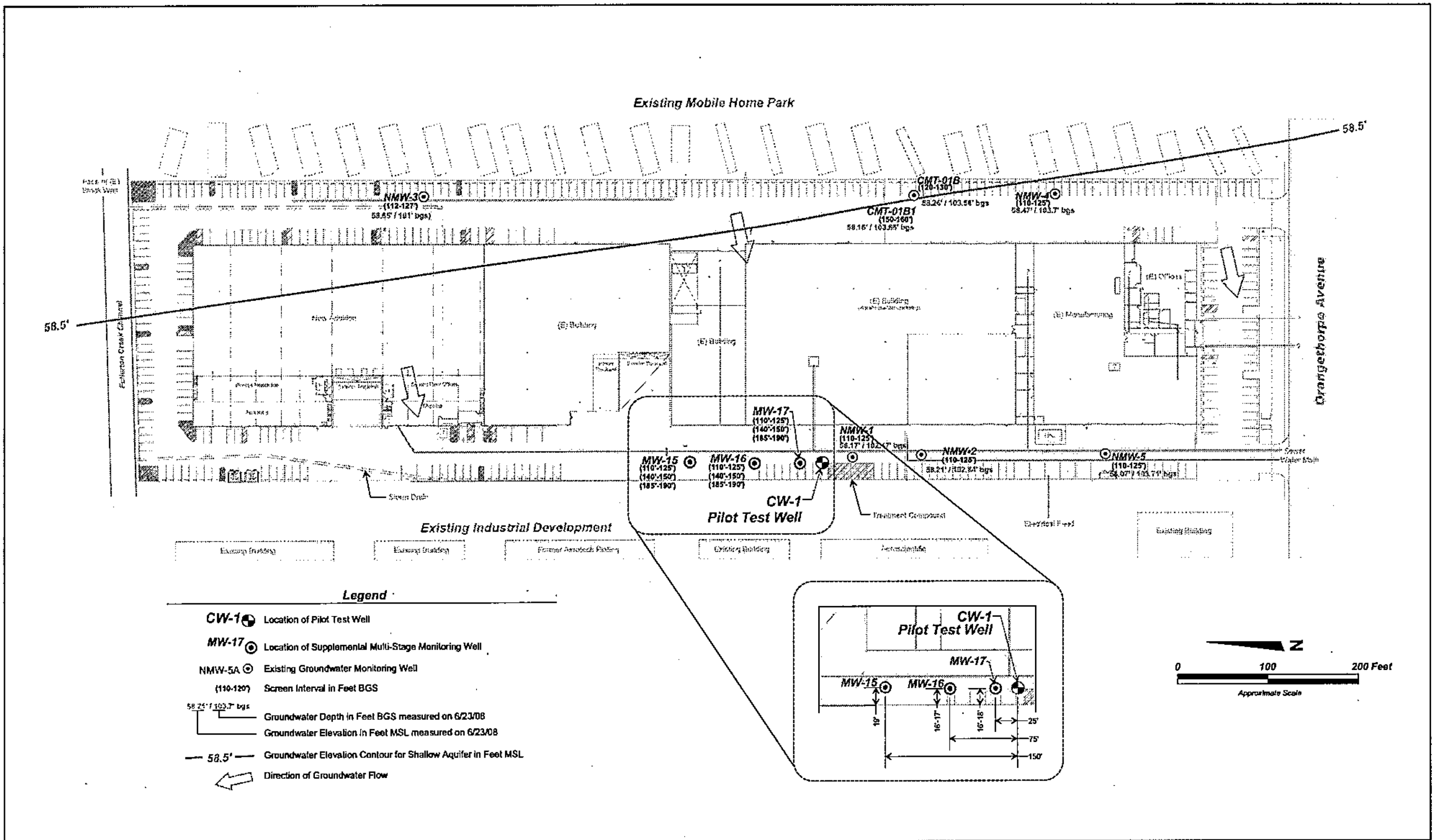
Notes:

[1] Analysis of VOCs to be in accordance with EPA 8260 protocol.

[2] Analysis of Chromium to include both Total Chrome and Chrome VI using EPA 6010B and EPA 7199 protocol, respectively.

[3] Bromate to be quantified using LC-MS analysis.

[4] The following parameters will be monitored approximately every 15 to 30 minutes in each well: Depth to water, dissolved oxygen, hydrogen peroxide, turbidity, conductivity, and ORP.



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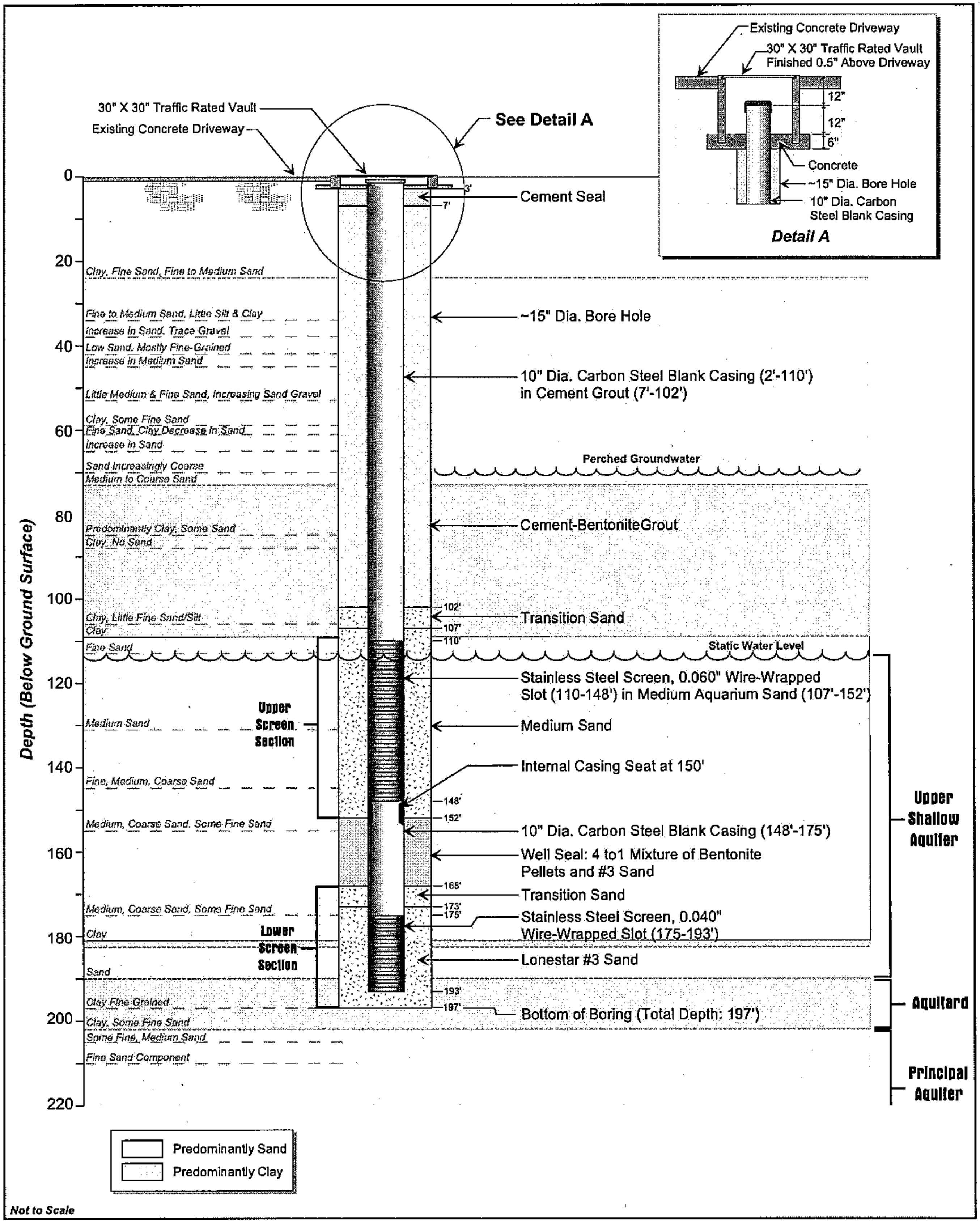
Y-12 Site Plan with Well Locations

Figure 1



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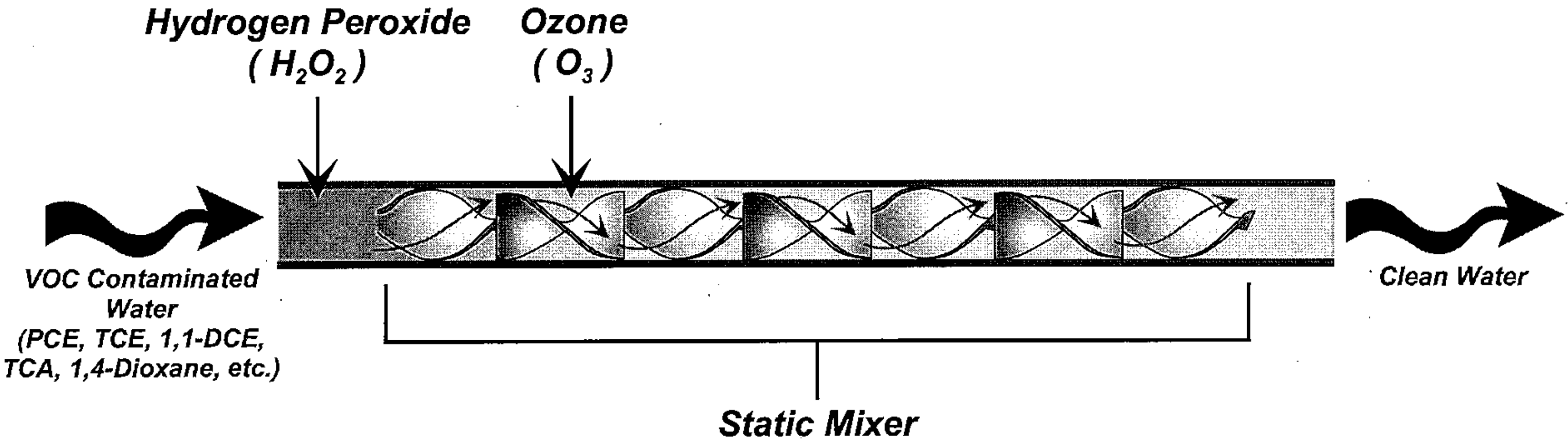
Schematic of Pilot Test Well CW-1

Figure 2



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Destruction of VOCs Using Advanced Oxidation With Ozone-Peroxide Alternative

Figure 3

Reaction #1:

$$2\ O_3 + H_2O_2 \longrightarrow 2\ OH^- + 3\ O_2$$

Ozone + Hydrogen Peroxide ⟶ Hydroxyl Radical + Oxygen

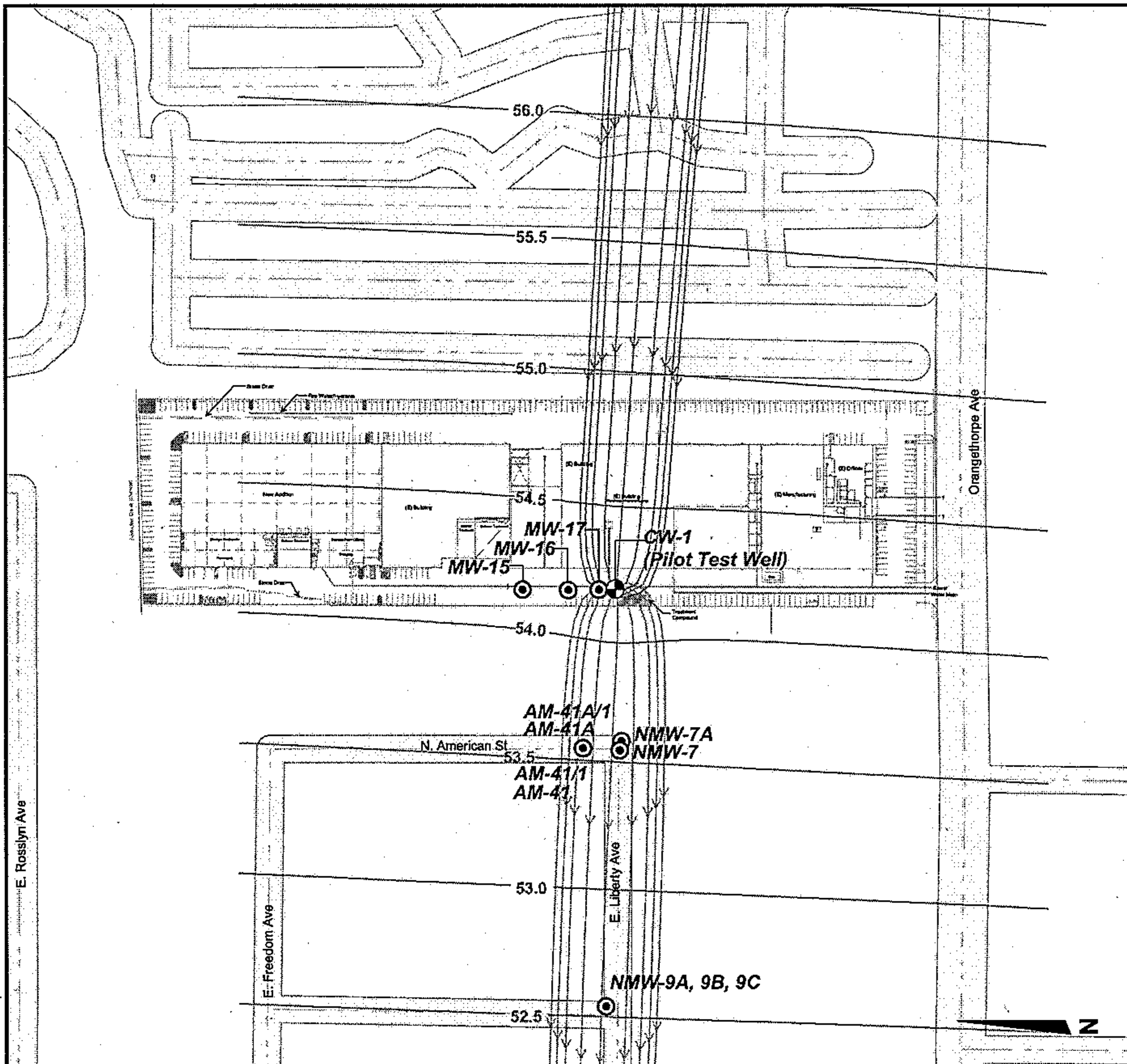
Reaction #2:

$$2\ [2\ OH^- + 3\ O_2] + C_2\ Cl_4 \longrightarrow 4\ HCl + 2\ CO_2 + 3\ O_2$$

Hydroxyl Radical + Oxygen + Tetrachloroethylene ⟶ Hydrochloric Acid + Carbon Dioxide + Oxygen

(Buffered ⟶ $CaCl + CO_2 + H_2O$)

Note: Total Mixing & Reaction Time Typically <10 Seconds



Legend

CW-1	Location of Pilot Test Well
MW-17	Location of Multi-Stage Monitoring Well
52.5	Modeled Groundwater Elevation Contour
	Modeled Extraction Pattern from Upper Zone Arrow Length Denotes Particle Travel Over 30 Days.
	Modeled Discharge Pattern to Lower Zone - Arrow Length Denotes Particle Travel Over 30 Days.

0 250 500 Feet

Approximate Scale

Conditions

- ***60 gpm Circulation Rate***
- ***Extract from Upper Zone of Shallow Aquifer / Discharge to Lower Zone of Shallow Aquifer***
- ***Particle Tracking Arrow Length = 30 Day Travel Time***

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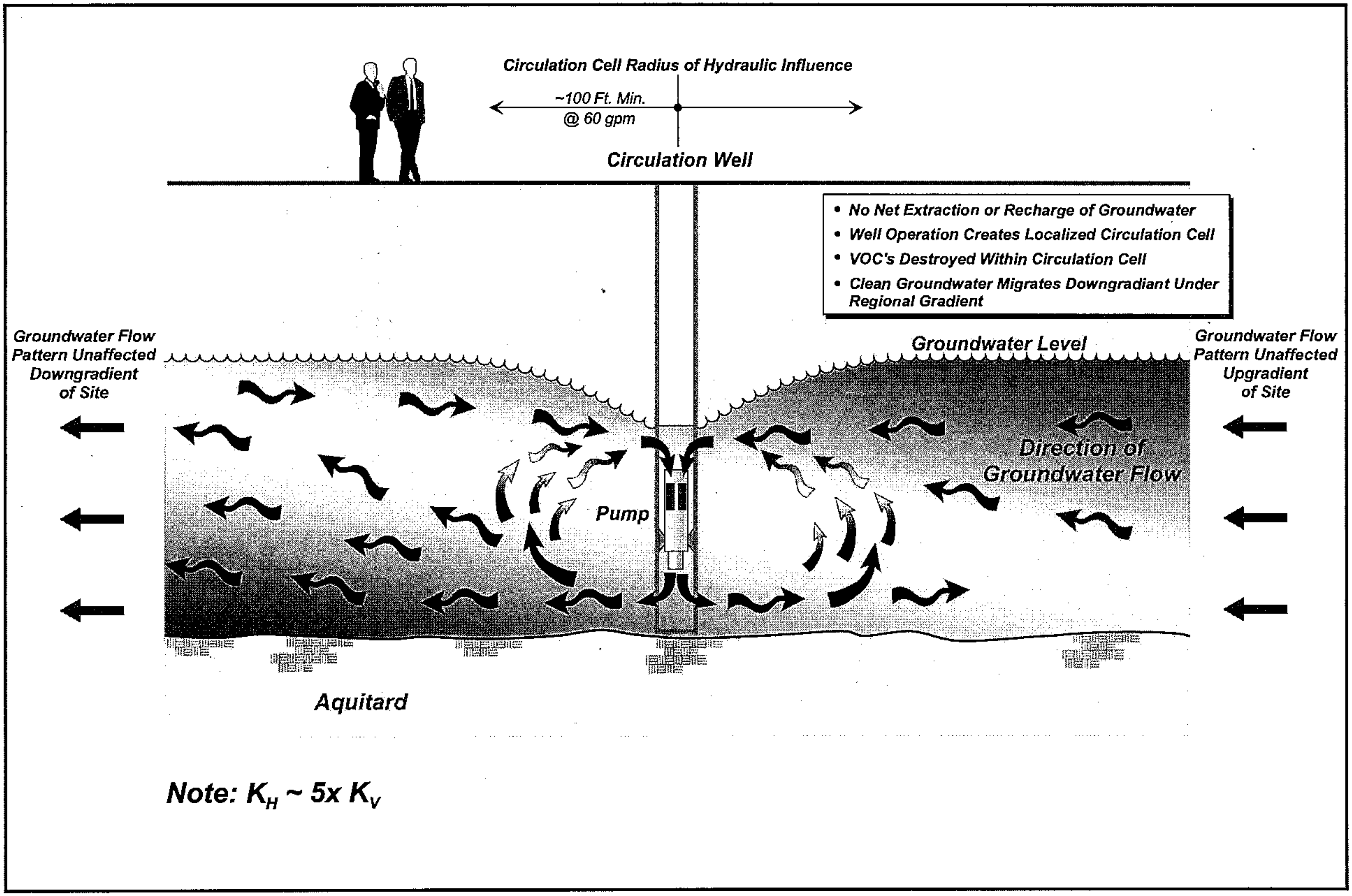
Groundwater Flow Pattern in Vicinity of Pilot Test Well

Figure 5



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Groundwater Flow Pattern Induced by Circulation Well

Figure 6

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Reaction #1:

$$H_2O_2 + U.V. \longrightarrow 2\ OH^-$$

Hydrogen Peroxide + Ultra-Violet Light ⟶ Hydroxyl Radicals

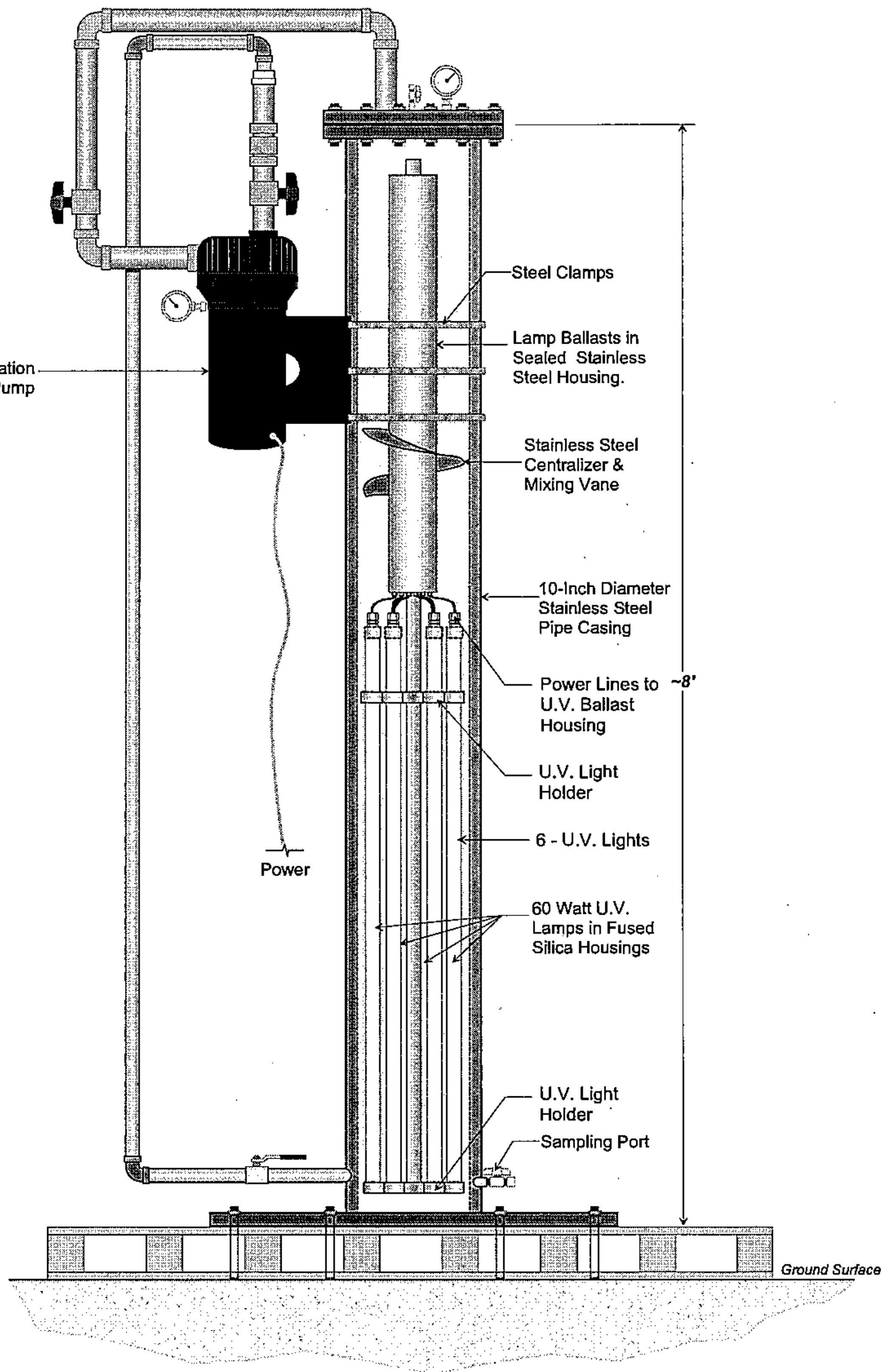
Reaction #2:

$$2\ [2\ OH^- + 3\ O_2] + C_2\ Cl_4 \longrightarrow 4\ HCl + 2\ CO_2 + 3\ O_2$$

Hydroxyl Radical + Oxygen + Tetrachloroethylene ⟶ Hydrochloric Acid + Carbon Dioxide + Oxygen

(Buffered ⟶ CaCl + CO_2 + H_2O)

Note: Total Mixing & Reaction Time Typically <60 Seconds



Scale as Shown

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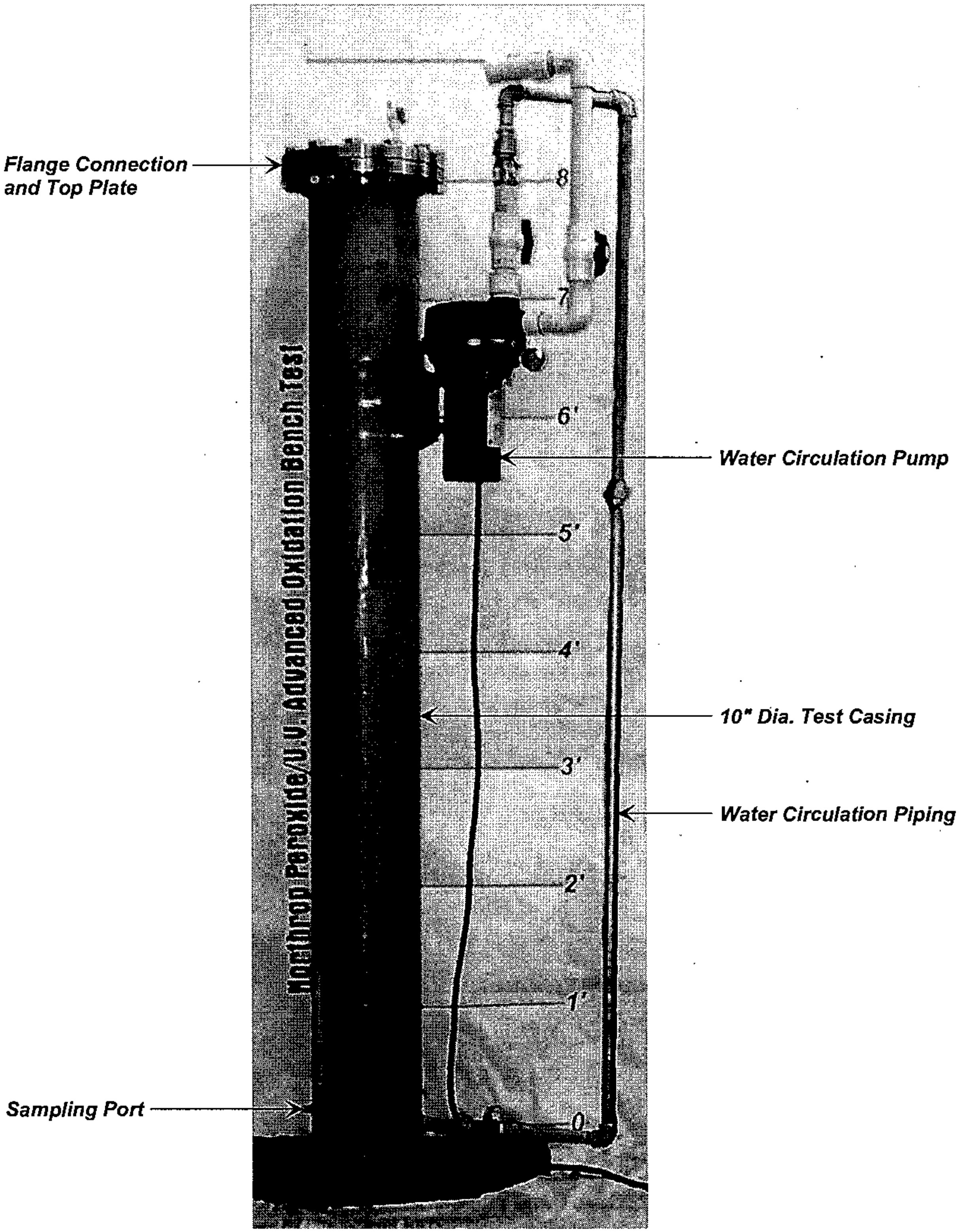
Schematic of U.V.-Peroxide Bench Test

Figure 8



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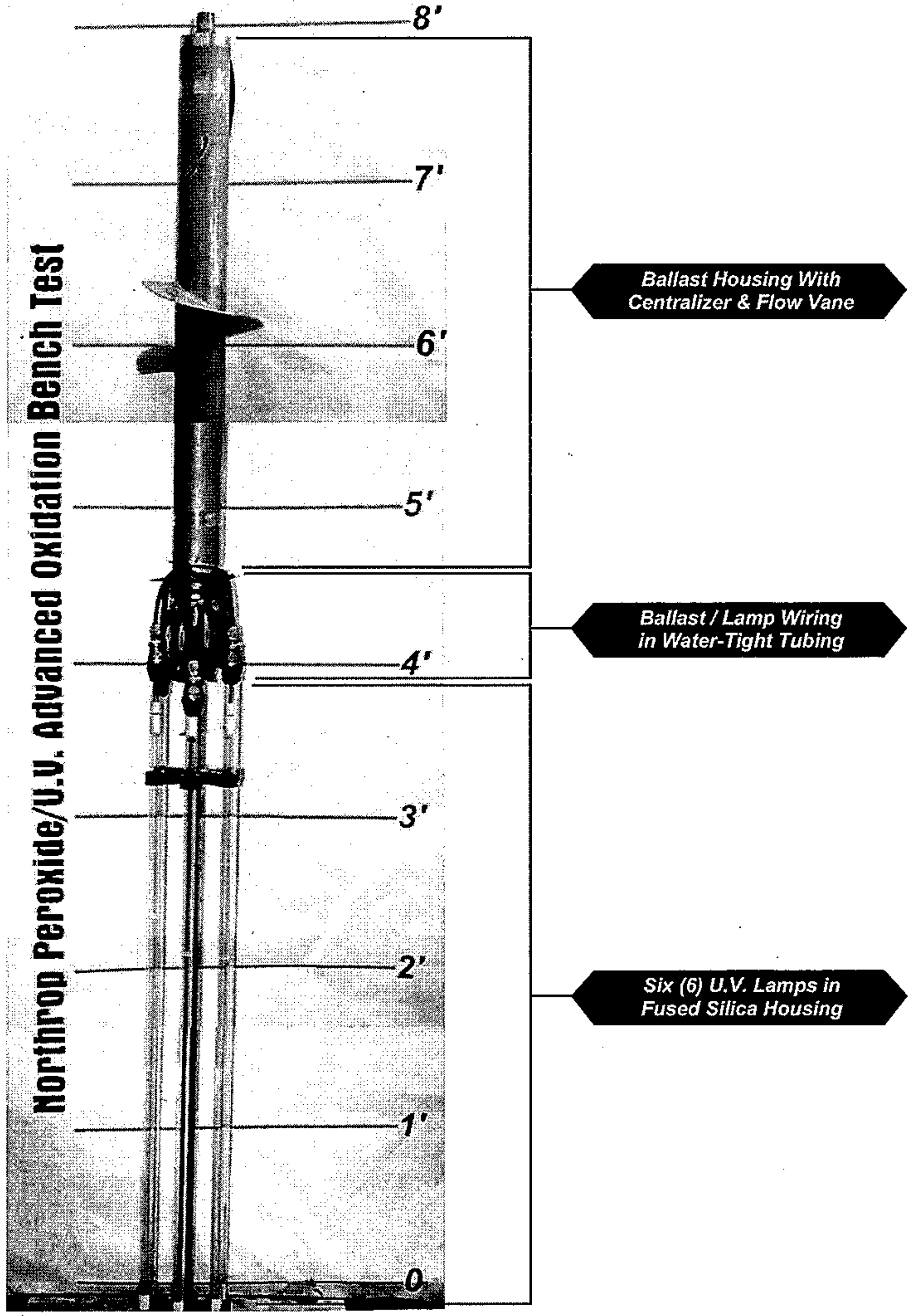
Photograph of UV-Peroxide Bench Test

Figure 9



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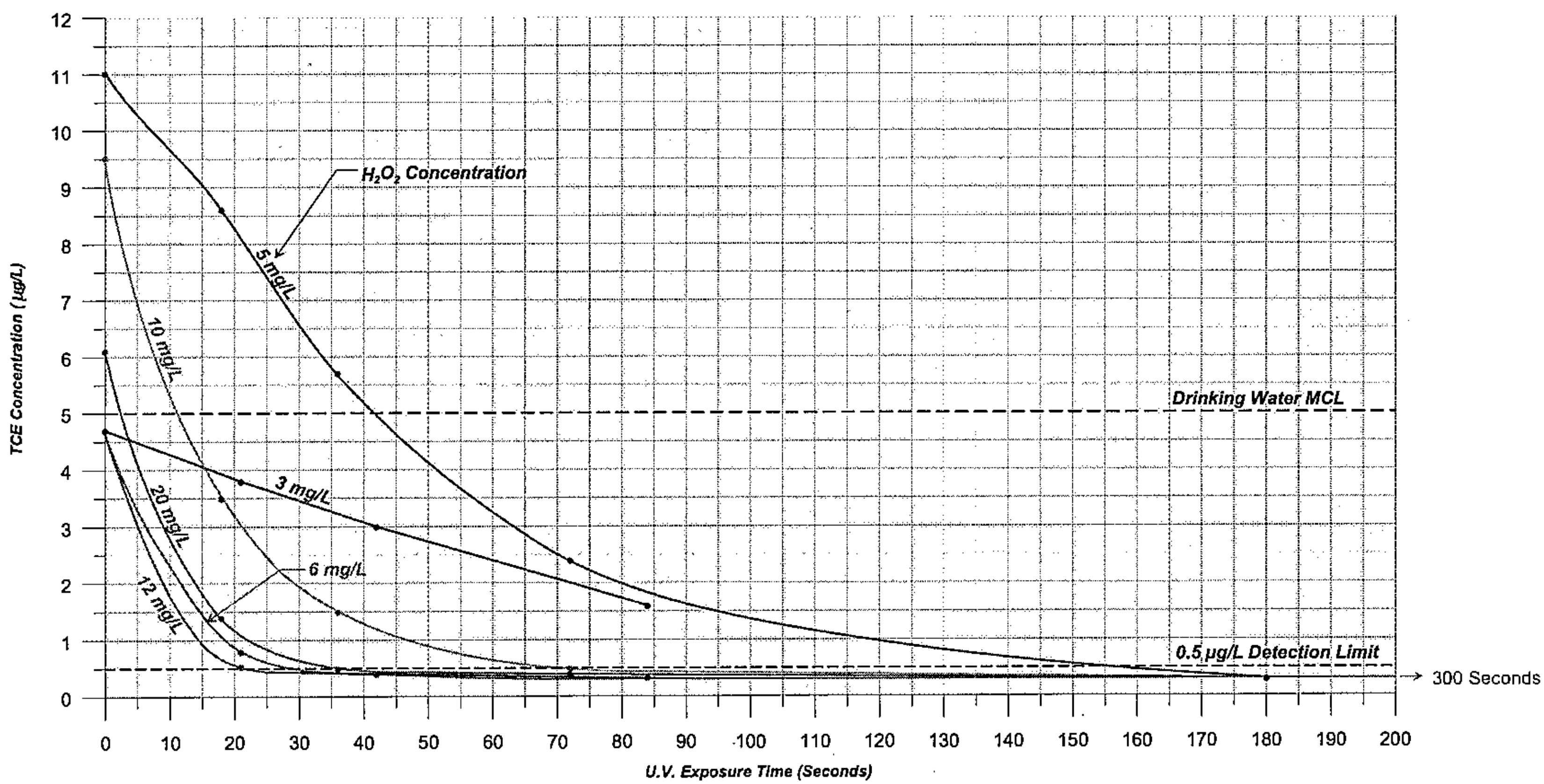
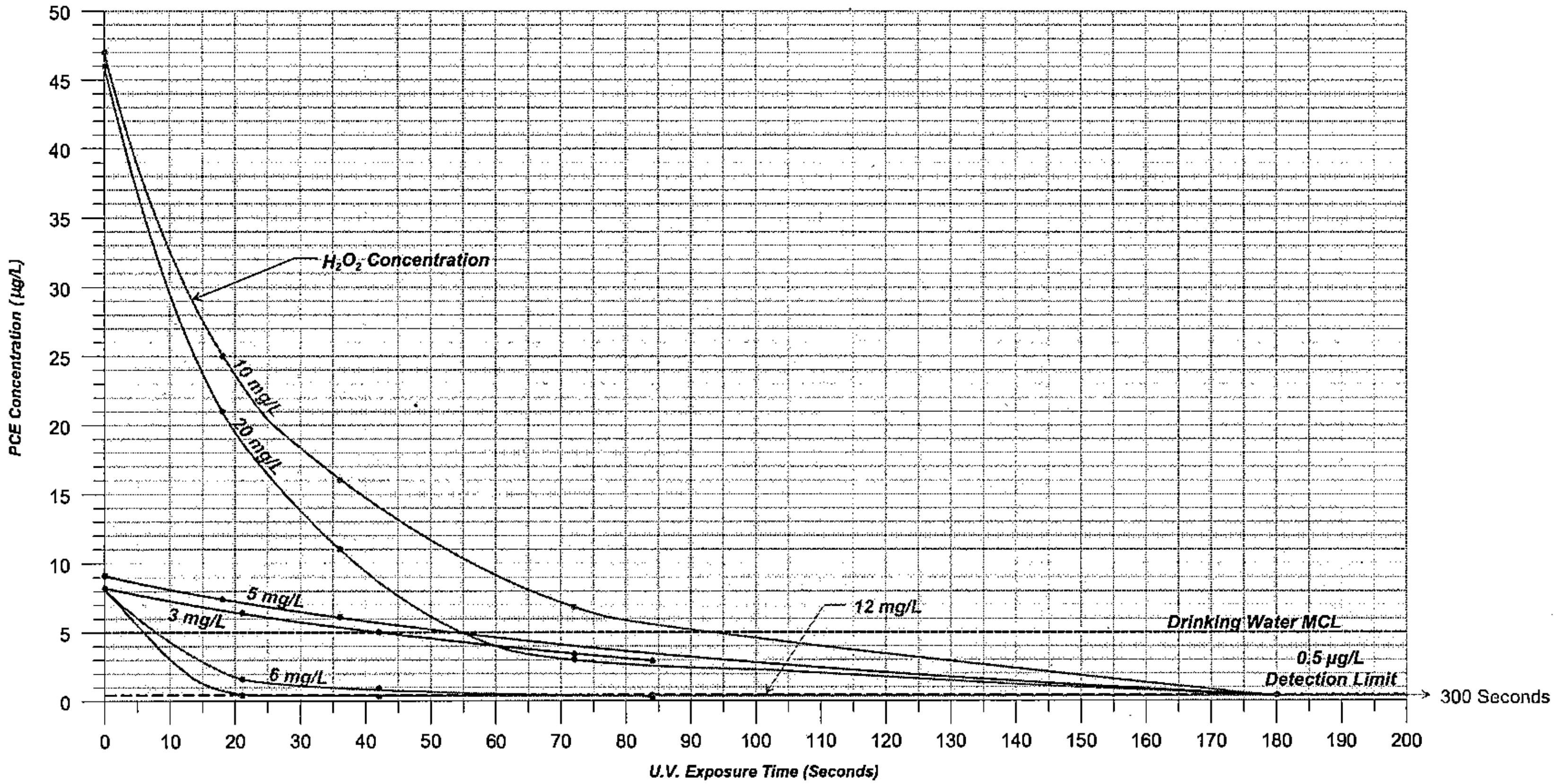
Photograph of UV-Peroxide Bench Test

Figure 10

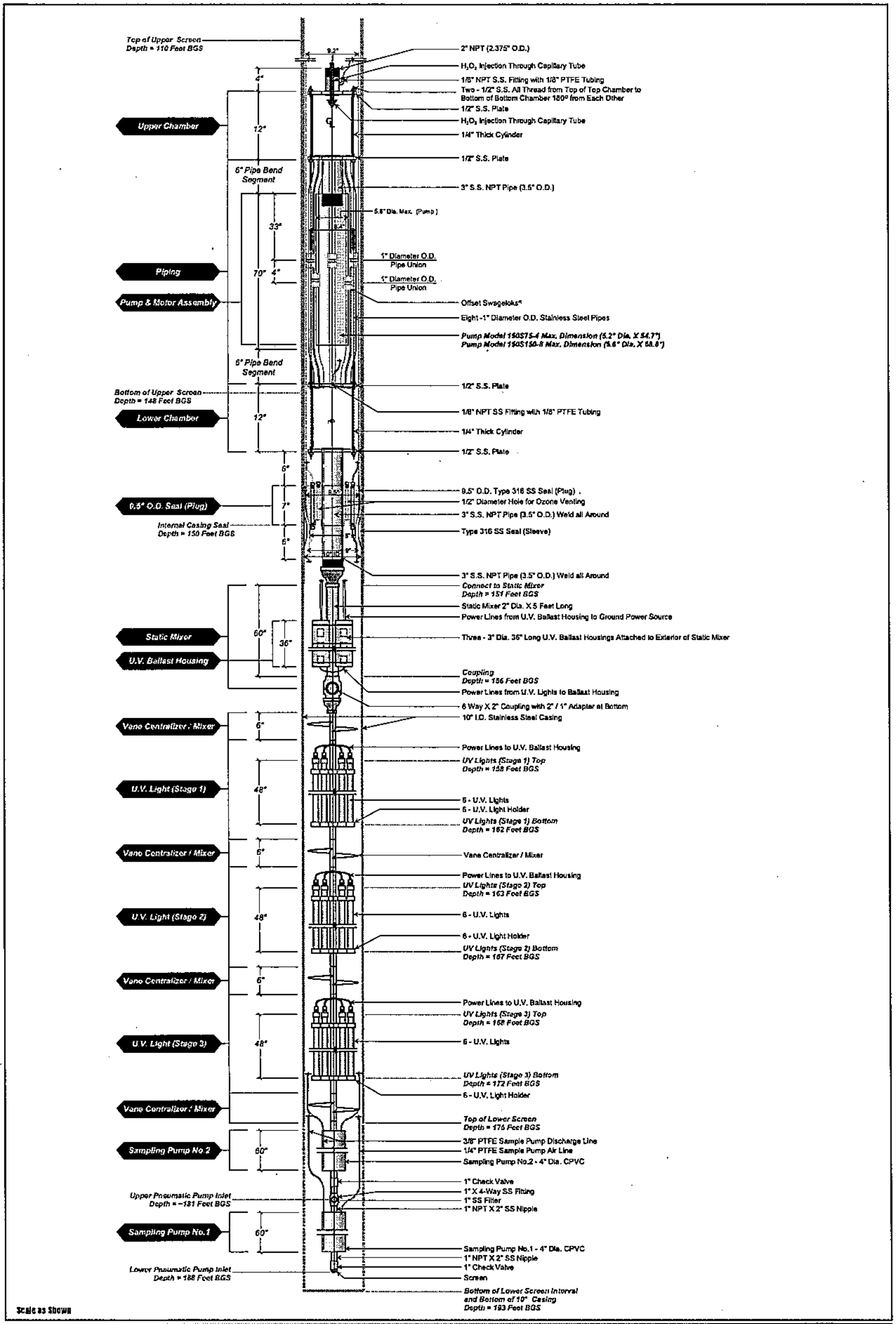


Attenuation Rate for TCE

Figure 11



PCE Concentration (µg/L)
50
45
40
35
30
25
20
15
10
5
0
H_2O_2 Concentration
10 mg/L
20 mg/L
5 mg/L
3 mg/L
6 mg/L
12 mg/L
Drinking Water MCL
0.5 µg/L
Detection Limit
300 Seconds
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
U.V. Exposure Time (Seconds)



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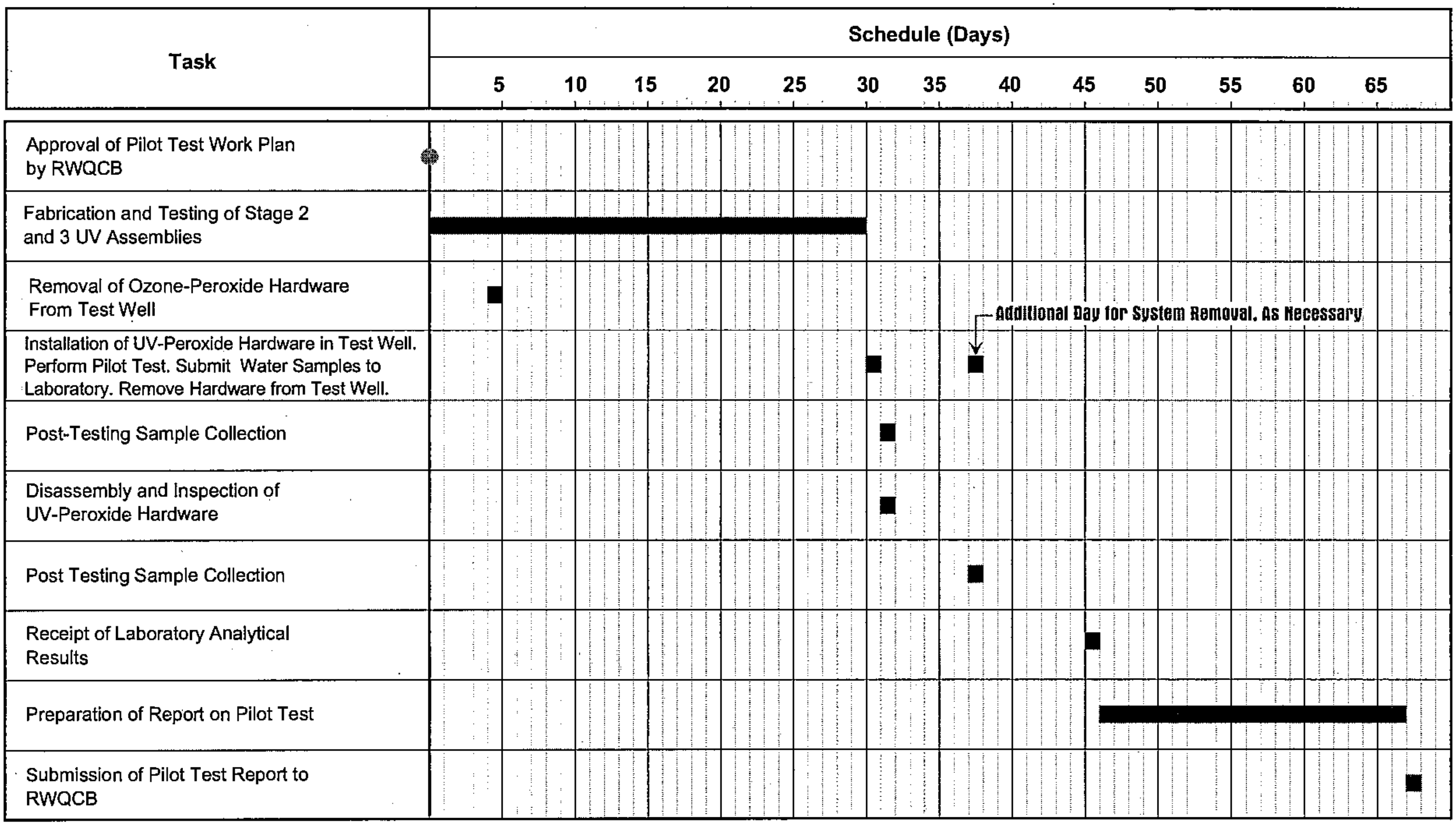
Schematic of Pilot Test Well Pump Assembly With U.V.-Peroxide Configuration

Figure 13



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Tentative Schedule for Pilot Testing of UV-Peroxide System

Figure 14

Attachment A

Bromate Analytical Results